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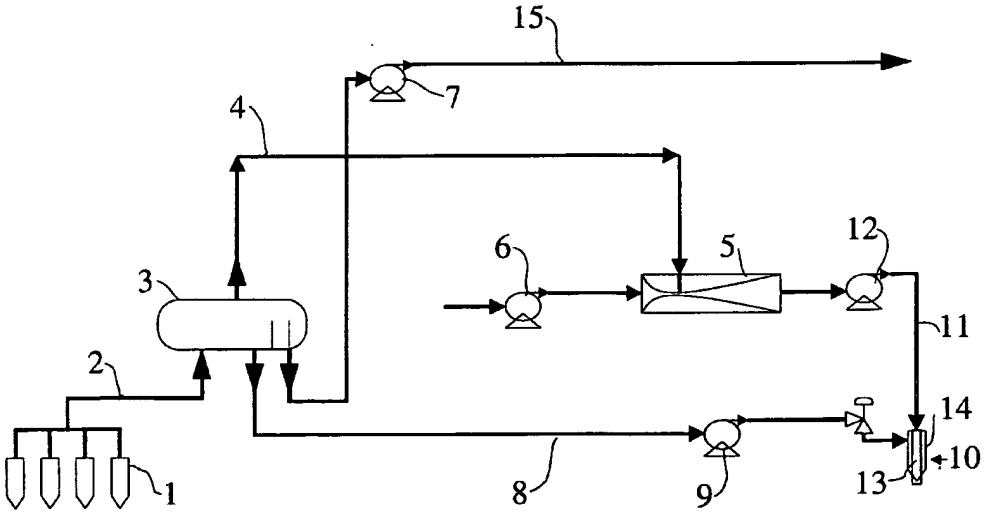
(54) Title: A METHOD AND A SYSTEM FOR INJECTING A GAS INTO A RESERVOIR



(57) Abstract: A method of injecting a gas into a reservoir. The method comprises the step of producing a gas hydrate from said gas and injecting the gas hydrate into the reservoir. A system for injecting a gas into a reservoir comprises a device (5) for producing from said gas a gas hydrate, which is to be injected into the reservoir.

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A METHOD AND A SYSTEM FOR INJECTING A GAS INTO A RESERVOIR

TECHNICAL FIELD

The present invention relates to a method and a system for injecting a gas into a reservoir.

The term reservoir should be regarded as any natural reservoir existing in nature, in particular any underground reservoir. Oil reservoirs as well as water reservoirs in the earth are included. Particularly included are reservoirs from which a natural resource is extracted and which, as a result of such extraction, are subjected to an unwanted pressure decrease.

BACKGROUND OF THE INVENTION

Oil production includes extracting oil from a reservoir, normally via one or more wells.

Normally, natural gas and water is extracted together with the oil and need to be separated therefrom. There are a plurality of different solutions regarding how and at which stage to separate the gas and water from the oil and how to make use of such gas.

As to the handling of the gas, the latter is traditionally either flared, stored and/or transported for further use, or re-injected into the reservoir.

Gas flaring is not allowed in many regions and will probably be forbidden in most regions in the near future for environmental reasons.

Transportation and/or storage of the gas will require the use of a compressor and a storage vessel and/or a pipeline for the transportation thereof. Especially for off-shore plants or plants where the amount of extracted gas is low, such arrangements will suffer from low cost efficiency.

Therefor, re-injection of the gas will in many cases be the most appropriate way of handling the extracted gas. Re-injected gas will also have the positive effect of contributing to the preservation of the pressure in the reservoir, something that is positive for the extraction of oil therefrom. However, traditional re-injection of the gas will require the use of a compressor and a separate injection well. The cost of such equipment is often much higher than the value of the gas, and can be an economical barrier to the development of marginal oil fields.

THE OBJECT OF THE INVENTION

One object of the invention is to suggest a method by means of which a gas can be injected into a reservoir in a cost-efficient and reliable way, well competitive with methods according to prior art.

There is also an object of the invention to suggest a system by means of which a gas can be injected to a reservoir in a cost-efficient and reliable way.

BRIEF DESCRIPTION OF THE INVENTION

The object of the invention is obtained by means of the initially defined method, which is characterised in that it comprises the step of producing a gas hydrate from said gas and injecting the gas hydrate

into the reservoir. Such a hydrate can be injected into the reservoir using only a liquid pump and without the need of a gas compressor.

The term hydrate, as used in this context, comprises special inclusion compounds having a crystalline structure known as clathrate. In such a structure gas molecules are physically entrapped or engaged in an expanded water lattice network comprising hydrogen-bonded water molecules. The gas molecules, preferably light hydro-carbon gas molecules and other associated gases physically react with water at elevated pressures and low temperatures to form ice-like compounds. The hydrate particles shall be of such character that they melt and release the gas and water when the temperature is sufficiently increased. Thereby preservation or even an increase of the pressure in the reservoir into which the gas/gas hydrate is injected can be obtained.

Preferably, the gas hydrate is produced by mixing the gas and water. Water has the advantage of having suitable physical properties for hydrate generation, being environmentally harmless and also, at least in connection to off-shore plants, being readily available.

According to one embodiment of the invention, the gas comprises natural gas that has been extracted together with and separated from oil from an oil reservoir. In case the reservoir into which the hydrate is injected is the same as said oil reservoir there is not only a question of injecting gas, but of re-injecting it into the reservoir. The invention includes re-injection of the gas hydrate into the same reservoir as the one from which the gas was originally extracted.

In the case of a reservoir located off-shore, that is an off-shore plant, the water used should comprise sea water. Such water already has the advantage of having a fairly low temperature and being readily

available. However, cooled produced water could also be used instead of or as a complement to cold sea water. The water temperature should be below approximately 10 °C, preferably below 5 °C.

Preferably, the water/gas ratio is chosen such that a liquid slurry consisting of water and gas hydrate is produced and that said slurry is injected into the oil reservoir. For natural gas and water, the preferred maximum amount of gas is approximately 13 wt %, the water amount then being approximately 87 wt %. This is the upper limit. If natural gas hydrates are produced at high pressure and low temperature, the upper limit might be reached. Creating hydrates near the hydrate formation curve, the amount of gas in the hydrates will be considerably lower than this limit. In order to make the slurry easy to pump during the re-injection excess water and/or surface active chemicals may be added to the hydrate slurry. Also any thermo active agent may be added to the slurry.

The hydrates can be produced from approximately 10 bar and higher depending on the temperature and gas mixture. Salty water will raise the hydrate curve and make it more difficult to create natural gas hydrates. When the hydrates are produced they are relatively stable also at atmospheric pressure, and they are meta-stable for negative temperatures, T<0 °C.

The hydrate can be produced, for example by injecting the gas into a water-filled system, or by injecting gas and water simultaneously in any suitable system or device. For example, the gas and water can be mixed in a venturi tube (jet pump), which can allow a lower operating pressure in a first stage separator (e.g. three phase separator for separating oil, gas and water). Other possible solutions of how to actually produce the hydrate are those mentioned in for example the international patent application WO 93/01153, Gudmundsson.

The object of the invention is also obtained by means of the initially defined system, characterised in that it comprises a device for producing from said gas a gas hydrate, which is to be injected into the reservoir. The system preferably comprises means for conducting the characteristic steps of the inventive method. The device preferably comprises a vessel with inlets for the gas and the medium with which it will form the hydrate, for example water. It should also comprise a means for generating an elevated pressure required in the vessel for producing the hydrate.

Accordingly, the gas hydrate producing device is adapted to mix the gas with water in order to produce the gas hydrate, preferably in such a way that easily pumpable hydrate slurry is obtained.

At least in the case of an off-shore plant, the system comprises means, preferably a pump or the like, for delivering sea water to the hydrate producing device.

Normally, the gas comprises natural gas extracted together with oil from said reservoir, and the system comprises a separator for separating the gas from the oil. Hence, the gas will be re-injected into the same reservoir as it was extracted from. However, the invention also covers the case in which the gas is injected into any other or neighbouring reservoir.

The system preferably comprises means for adding warm water, preferably production water or top side process water to the gas hydrate that is to be injected into the reservoir. Production water is water that has been extracted together with oil from an oil reservoir and then separated from the oil. Such water will have the effect of improving the injectivity of the slurry by melting the hydrates, making it easier

to re-inject the slurry without blockage or clogging in the re-injection well. The warm water and the hydrate slurry need not necessarily be in direct contact with each other. For example, the warm water, such as production water, can be conducted in annular tube or pipe arranged directly outside the pipe for conducting the hydrate to the reservoir and thereby heating the outer peripheral regions of the hydrate. Alternatively the warm water can be conducted in the inner tube and the slurry in the annular tube. As a matter of fact, according to one aspect of the invention any hot medium (process water, production water, hot cooling water, etc) may be used for the purpose of heating the hydrate slurry just before the latter is injected into the reservoir. Accordingly, a medium of significantly higher temperature than the hydrate slurry is brought into a heat exchanging relationship with said slurry before injection of the latter into the reservoir.

In the case of an off-shore plant for an off-shore reservoir, the gas hydrate production device is operating at a sub-sea level according to one embodiment.

Further features and advantages of the invention are included in the following detailed description and in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention is described in further detail with reference to the drawing in which the only figure is a schematic diagram of the system of the invention according to one embodiment.

DETAILED DESCRIPTION OF THE INVENTION

The figure shows a first embodiment of the system according to the invention. Also shown or indicated are parts of an oil extraction plant, the system being a part of that plant.

The plant comprises a plurality of wells 1 forming a so called production tree and by means of which oil is extracted from a reservoir or cavity (not shown). Gas, water and other particulate material such as sand is normally also extracted as a bi-product to the oil.

The wells 1 are connected via a pipeline 2 or the like to a first separator 3, which in this embodiment is a three phase separator for separating oil, water and gas from each other. Preferably, the separator is a gravity separator, but it should be understood that also other types of separators might be used instead or as a complement to the one shown in this embodiment. For example, a separator for separating solid particles such as sand from the extracted oil might as well be included in the three phase separator, which then becomes a four phase separator, or separately upstream the three phase separator.

From the three phase separator the gas is conducted via a pipe 4 to a gas hydrate producing device 5. No compressor is needed. The device 5 comprises a vessel into which the gas is injected. Inside the vessel there is an elevated pressure (above atmospheric pressure). Water is also introduced into the vessel. The device 5 preferably comprises a venturi tube for mixing gas and water, as shown in the figure. The device 5 is arranged at a sub-sea level or a top-side level and the water is sea water, which is pumped into the vessel by means of a pump 6. In accordance with the results of recent research and development, a natural gas hydrate is thus formed by injecting the gas into a wa-

ter-filled system, here the vessel 5. In order to control the conditions in the vessel a water/gas ratio control system (not shown) including pressure and/or temperature sensors, gas and water flow meters, and control apparatus for controlling the amount of introduced water etc. should be part of the inventive system. The water/gas ratio should be such that a gas hydrate-water slurry is formed in the device 5.

Even though the invention is applicable to all kinds of oil-fields, land based as well as off-shore fields, it is particularly advantageous for off-shore fields, where sea water is readily available and where re-injection of the gas into the oil reservoir is preferred instead of flaring or storage and further export via shipping or pipelines. Off-shore, the separator 3 and the device 5 could either be arranged top side at the platform or at a sub-sea level. The invention includes both alternatives.

Top side arrangement results in no sub-sea processing. The required pressure, between 30 and 60 bar for normal sea water temperature, for generating the hydrate could then be used in the 1st stage gravity separator 3. The gas from further separators on the platform can then be used as fuel gas on the latter.

For sub-sea arrangement of the device 5, the separator 3 and the pump 6 are preferably arranged at a sub-sea level as well. A sub-sea pump for pumping oil from the separator 3 to the topside is then likely to be needed. Therefor, such a pump 7 has been indicated in the figure. The sea water for injection can be obtained locally at the sub-sea installation or transported from the topside, enabling pre-treatment of the water. Such pre-treatment may preferably include the addition of surface active chemicals for improving the hydrate pumpability, removal of oxygen from the water, addition of biocides,

etc. Also a thermo active agent such as methanol might be added to the water. Accordingly, the inventive system includes means or devices (not shown) for such pre-treatment of the water.

From the separator 3 separated production water, which is warmer than the sea water, is conducted via a pipe 8 to, by means of a pump 9, to a combined water-hydrate injection device 10. The hydrate slurry formed in the hydrate producing device 5 is also conducted, via pipe 11 and by means of a pump 12, to the injection device 10.

The injection device 10 may be arranged in a plurality of ways. Here it is proposed to comprise a first tube 13 and a second tube 14 that are generally coaxial and define an inner flow path for the hydrate slurry and an outer annular flow path for the production water. The warmer production water contributes to the melting of the slurry just before the latter entries into the reservoir. As a supplement or substitute for the means 8, 9, 10 for enabling the production water to heat the hydrate slurry, the system may comprise any suitable means for enabling any hot medium, such as hot cooling water or any other medium already in use in an oil extraction plant or system, to exchange heat with the hydrate slurry. Chemicals or agents for melting the hydrate could also be added to the hydrate slurry in the region of or downstream the pump 12. An example of such an agent is salt, methanol or glycol.

Alternatively the slurry is mixed with the production water. However, mixing with production water may result in precipitation of sulphate scale and hydrate melting near the top of the injection well. One solution to the scaling problem is to have a sulphate removal unit included in the system. Alternatively or as a supplement, a scale inhibitor, known per se, is introduced into the system in which the

slurry and the production water are mixed. The system thereby comprises any suitable means for adding such an inhibitor.

Oil separated from the gas and the production water in the separator 3 is further transported via one or more pipes 15 to a top side platform or all the way to land where it is taken further care of. Normally a plurality of additional separators (not shown) for further separation of rest gas and rest water will be needed somewhere downstream the first separator 3. Such additional separators are typically located on the platform in todays plants, but might as well be located at a subsea level in the future.

Above, the invention has been described by way of example. A plurality of alternative embodiments will therefor be obvious for a man skilled in the, however without going beyond the scope of the invention, as defined in the appended claims supported by the description and the drawing.

For example melting of the hydrate slurry may begin as soon as the slurry has passed the injection pump 12 in order to promote efficient injection of the gas and water to avoid clogging. A plurality of ways of heating the slurry should be obvious for a man skilled in the art without going beyond the scope of the invention.

The formation into which the hydrate slurry is injected could be any natural reservoir, such as a water reservoir located at a level above an oil reservoir from which the gas has been extracted. It also might be any hydro carbon reservoir, including an oil and/or a gas reservoir.

PATENT CLAIMS

1. A method of injecting a gas into a reservoir, **characterised in** that it comprises the step of producing a gas hydrate from said gas and injecting the gas hydrate into the reservoir.

2. A method according to claim 1, **characterised in** that the gas hydrate is produced by mixing the gas and water.

3. A method according to claim 1 or 2, **characterised in** that the gas comprises natural gas.

4. A method according to any one of claims 1-3, **characterised in** that the gas comprises natural gas that has been extracted together with and separated from oil from an oil reservoir.

5. A method according to any one of claims 1-4, **characterised in** that the reservoir is an off-shore reservoir and that the water is sea water.

6. A method according to any one of claims 2-5, **characterised in** that the water/gas ratio is chosen such that a liquid slurry consisting of water and gas hydrate is produced and that said slurry is injected into the reservoir.

7. A method according to any one of claims 2-5, **characterised in** that at least one surface active agent is added to the water that is mixed with the gas.

8. A method according to any one of claims 1-7, **characterised in** that the reservoir is an off-shore reservoir and that the production of the gas hydrate is performed at a sub-sea level.

9. A method according to any one of claims 1-8, **characterised in** that the hydrate is produced by injecting the gas into a water-filled system.

10. A method according to any one of claims 1-9, **characterised in** that the reservoir into which the gas is injected is an oil reservoir.

11. A system for injecting a gas into a reservoir, **characterised in** that it comprises a device (5) for producing from said gas a gas hydrate which is to be injected into the reservoir.

12. A system according to claim 11, **characterised in** that the gas hydrate producing device (5) is adapted to mix the gas with water in order to produce the gas hydrate.

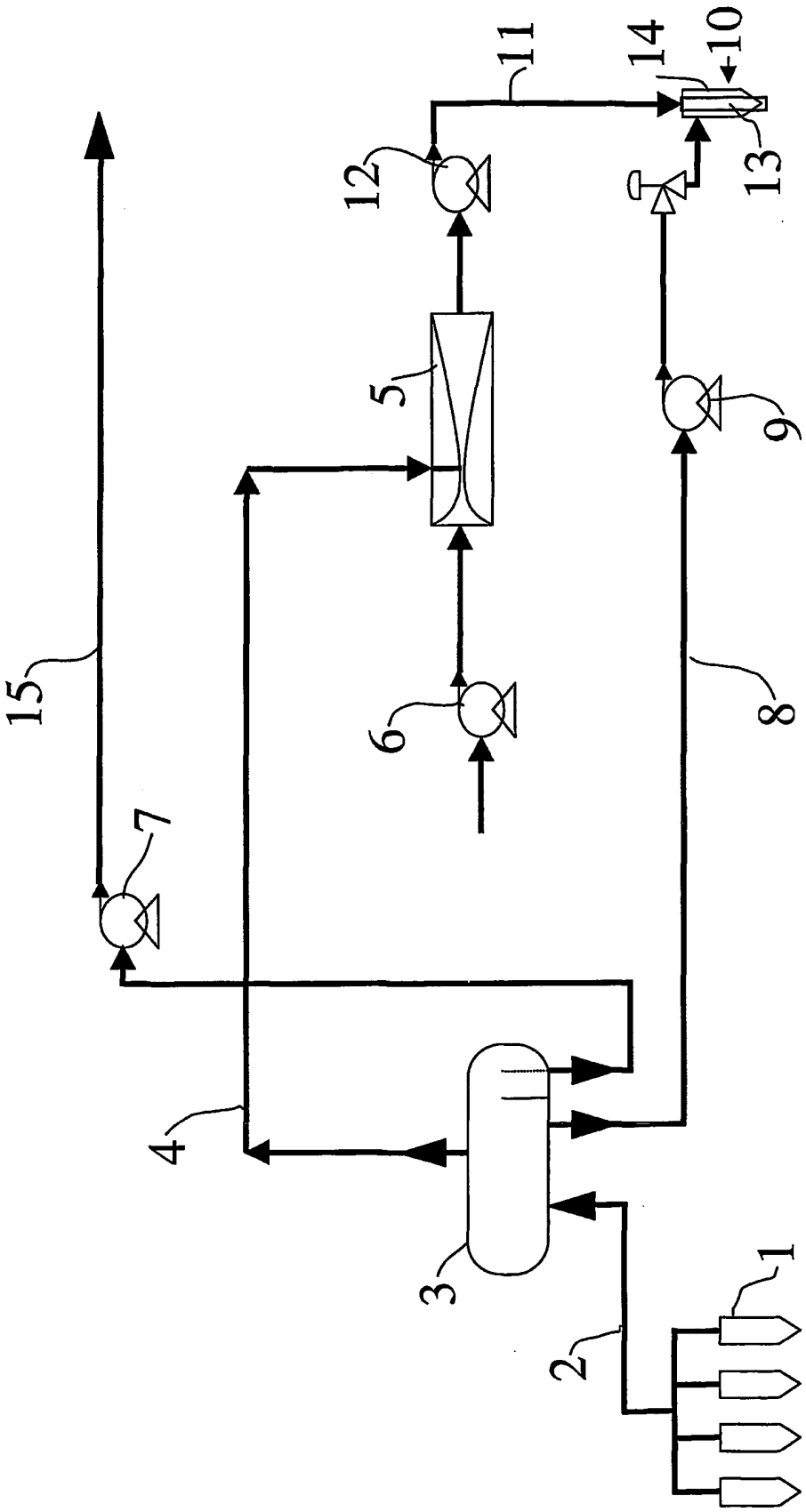
13. A system according to claim 12, **characterised in** that the gas comprises natural gas extracted together with oil from an oil reservoir, and that it comprises a separator (3) for separating the gas from the oil.

14. A system according to claim 13, **characterised in** that it comprises a means (4) for conducting the gas from the separator to the gas hydrate production device (5).

15. A system according to any one of claims 11-14, **characterised in** that it comprises means (8, 9) for adding production water to the gas hydrate that is to be injected into the reservoir, said production water having been extracted together with oil from an oil reservoir and then separated from the oil.

16. A system according to any one of claims 11-15, **characterised in** that the reservoir is an off-shore reservoir and that the gas hydrate production device (5) is operating at a sub-sea level.

17. A system according to any one of claims 11-16, **characterised in** that the reservoir into which the gas is injected is an oil reservoir.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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 01/01560

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: E21B 43/40, E21B 43/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4813484 A (RANDY D. HAZLETT), 21 March 1989 (21.03.89) --	1-17
A	US 4424866 A (PATRICK L. MCGUIRE), 10 January 1984 (10.01.84) --	1-17
A	FR 2514071 A1 (CHAUDOT GERARD), 8 April 1983 (08.04.83) --	1-17
A	EP 0780167 A1 (CANON KABUSHIKI KAISHA), 25 June 1997 (25.06.97) -- --------	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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